X-Ray Focusing with Refractive Optics

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Beamline(s): **X8A**

Introduction: As an alternative to reflective focusing of x rays, such as obtained in Wolter type optics, and to diffractive focusing as demonstrated in zone plates, it is possible to achieve focusing of x-rays with refractive optics, i.e., with lenses. There is a parameter space in which one can take advantage of the fact that the electrons bound in a lens material act as a plasma, with an index of refraction that is slightly less than one for x ray energies. This effect has been previously demonstrated (Snigirev, *et al,* 1996). The effect, which is dependent on electron density and x-ray energy, is rather weak, so that a series of such lenses, termed a compound refractive lens (CRL) must be used to generate focal lengths of one to two meters for x ray energies of a few keV. X-ray absorption in the lens material is an important consideration in order to maintain reasonable transmission efficiencies, and so this parameter space confines the physical size of the individual lenses to typical submillimeter diameters. In the future practical lens systems will incorporate arrays of CRLs to increase the collecting area. Theoretically, very high angular resolution (e.g., one arc-second) is achievable, and, as an example, one of the applications we are considering at Los Alamos is a satellite-borne x-ray imager for 6-keV Fe-line emission from astrophysical sources. Other applications include the focusing of synchrotron beams to high-intensity focal spots.

Methods and Materials: Low atomic number materials (e.g., polystyrene) minimize x-ray absorption, and so this is one of the first materials we have used to fabricate biconcave parabolic microlenses at the Los Alamos National Laboratory's target fabrication facility. Here micro-machined parabolic mandrels have been generated, and used for molding the 600-micron diameter plastic concave lenses. An optical profilometer characterized the surface figure and quality of the individual lenses. Our first attempt at focusing x rays with a CRL took place in August, 2000, at the X8A beamline, where we installed an x-ray CCD camera as the primary diagnostic tool.

Results: In spite of some CRL alignment problems, we did find evidence for two-dimensional x-ray focusing at 5.5 keV, by scanning the beamline's x-ray energy over the range of 5.0 keV to 5.9 keV and recording the focal spot distribution with the CCD camera. Since CRLs are designed to focus at one particular x-ray energy, this is an effective method for demonstrating the effect. At 5.5 keV the focal spot diameter was minimized.

Conclusions: Refractive optics may eventually offer a simpler, less expensive method to focus x rays for imaging purposes, or to generate high-intensity focal spots at synchrotron facilities. We will continue our research program into CRL technology in FY01, by investigating other lens materials and designs, and by improving our diagnostic capabilities for additional data runs at the NSLS.

References: A. Snigirev, V. Kohn, I. Snigireva, B. Lengeler, "A Compound Refractive Lens for Focusing High-Energy X-Rays", NATURE, **384**, *49*, 1996